Effects of Benthopelagic Animals on Seabed Properties

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LONG-TERM GOALS

The long-term goals of this research are to improve the ability of benthic biologists and biological oceanographers to observe life on and in the seabed; to describe the interactions between the animals that live there, their neighbors and their food; to improve our understanding of the coupling between the benthic and the pelagic communities; and to assess biologically mediated changes in those physical properties of the seabed that affect the scattering and penetration of sound from and into the bottom.

OBJECTIVES

Direct observation of animals that live on or in the seabed is exceptionally difficult. This is especially true in areas with characteristically poor visibility or in water that is too deep to allow divers to spend much time near the bottom. Little attention has been given to developing instrumentation and sensors that would allow remote observation of benthic animals for long periods at high spatial and temporal resolution. We are developing high frequency acoustic sensors, sensor deployment and data processing methods to fill this gap, thereby improving the information that benthic ecologists can access about benthic and benthopelagic animals and the seabed environment. Monitoring bottom and near-bottom animal distributions and processes at intervals of minutes and resolutions of tens of cm or better may also be useful in determining the causes of short term temporal changes in acoustical scattering and sound propagation in the seabed over a wide frequency band.

APPROACH

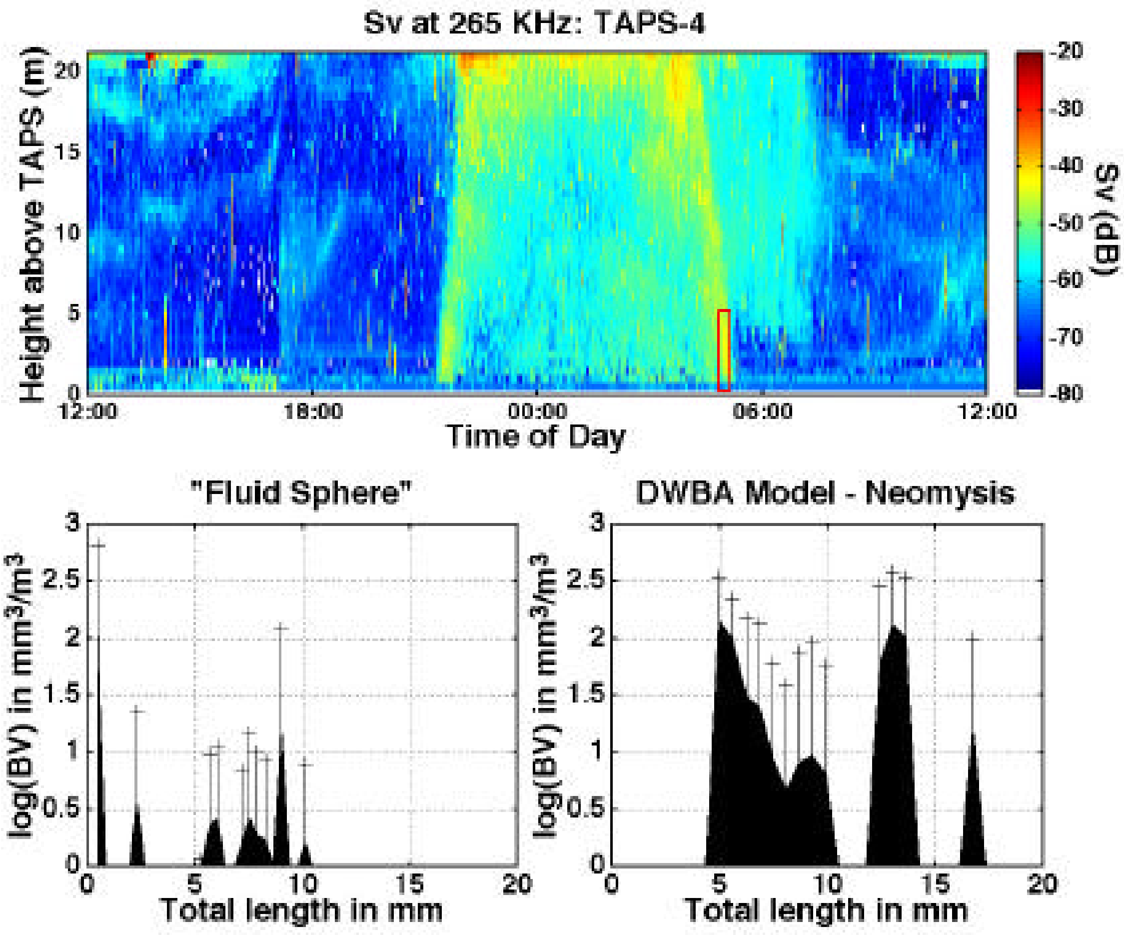
Using multi-frequency acoustical zooplankton sensors operating at 265, 420, 700, 1100, 1850 and 3000 kHz in a variety of coastal marine environments, we have detected the emergence and re-entry of small benthopelagic crustaceans at dusk and dawn (Alldredge and King, 1980) and on current cues (Roman, Holliday and Sanford, 2001). These behaviors change the millimeter-scale roughness of the seabed at least twice a day. Animals may also burrow into the seabed, changing the volume heterogeneity of the subsurface in the upper meter. These phenomena have been identified as likely contributors to an observed anomalous penetration of the seabed by sound in the kHz and tens of kHz frequency range (Thorsos, Jackson and Williams, 2000; Lopes, 1996). Our approach to achieving a better understanding of how biology modifies the seabed involves a combination of direct observation with high frequency acoustics in various littoral environments and model-based inverse processing of the data acquired. This allows us to interpret the acoustical measurements in terms of observed distributions and behaviors of biological organisms in relation to cues such as light, food, predation and currents near the seabed.

WORK COMPLETED

During the last year we have focused on advancing our ability to distinguishing elongate zooplankton (e.g., mysids) which we have observed to be important members of migrating shallow water benthopelagic communities from plankton of other shapes. To develop and test appropriate analysis methods we used data from several field projects, including the SAX-99 site off West Destin, FL and two small fjords on Orcas Island, WA (West Sound and East Sound). We implemented a multi-model, multi-frequency inverse computer code which includes both a generic scattering model for copepod-like zooplankters (the truncated fluid sphere model) and a model for elongate scatterers such as mysids or euphausiids that is based on a distorted wave Born approximation (DWBA) approach (McGehee, O’Driscoll, and Martin-Traykovski, 1998 ; Martin-Traykovski,. O’Driscoll, and McGehee, 1998).

RESULTS

The new two model inverse algorithm is based on an old idea (Holliday, 1977) but has only now been implemented as an “easy-to-use” tool. Using new inverse code based on this approach, we simultaneously and optimally calculated size spectra for the zooplankton and micronekton at particular times and depths, by using models for zooplankters of two different shapes (spheroidal, or small crustacean-like and elongate, or shrimp-like). Our truncated fluid sphere model (Holliday, 1992) was used to describe the copepod-like scatterers. McGehee’s code which implements a 2-D distorted wave Born approximation (DWBA) model was used to represent the more elongate bent cylinder type of scatterers, e.g., euphausiids, small shrimps and mysids (McGehee, O’Driscoll, and Martin-Traykovski, 1998). An example of a two-model inverse calculation focused on a re-entry event at a site in West Sound on Orcas Is. is given below.



An acoustical scattering record collected at 265 kHz in West Sound, Orcas Is. on July 28-29, 1995 reveals a strong dusk emergence and a dawn return of benthopelagic taxa to the seabed. Calculated sizes are shown for copepod-shaped and mysid-shaped scatterers at the times and depths indicated by the position of the small box in the upper panel. Emergence trap and net samples collected at this site both strongly implicate several distinct sizes of Neomysis kadiakensis as the source of the strong diel migration signals observed acoustically (Kringel, Jumars and Holliday [submitted]). For the data bounded by the analysis "box, the mean estimated biovolumes plus the standard deviations at size are also indicated by the vertical lines extending above the shaded areas".

IMPACT/APPLICATION

Small-scale (mm) changes occur when individual benthopelagic zooplankters emerge from and re-enter the sediments. These animals also contribute to volume heterogeneity in the sediments. Predator-prey interactions can also change both the local bottom roughness at centimeter scales and the physical characteristics within and near the localized disturbances created when the fish feed on zooplankton in the act of emerging or re-entering the seabed. These effects, in turn, change the local surface acoustical impedance, modifying both the propagation and scattering of sound from and within the seabed. Our data indicate that biological activity by both predator and prey, and the consequent changes in scattering that result may not be evenly spread over the day. Both light and current near the seabed appear to trigger and modify these behaviors. Thus, sound may penetrate and propagate in different ways throughout the day in response to these biological behaviors.

TRANSITIONS

The observations made in our part of the SAX-99 program offer explanations for at least some of the variability one observes in acoustic scattering from the seabed and in the penetration and propagation of sound within the bottom. Understanding these phenomena at a level that will eventually allow modeling and prediction of both absolute scattering and propagation, and the variability in those quantities from descriptions of the physical and biological environment, are long-term goals of a large community of academic, industry and navy scientists.

RELATED PROJECTS

We continue to work closely with Peter Jumars, Keli Kringel and Liko Self (http://www.ume.maine.edu/~marine/jumars/paj.html), all of whom have had, or currently have, related ONR-funded projects. In some of our work on benthopelagic species we are applying the 2-D DWBA modeling methods developed by McGehee and his co-PIs in previous ONR-sponsored projects (as cited previously). We have been able to move ahead more quickly by using several results, including the DWBA computer codes, from that work.

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PUBLICATIONS

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